F I G. 1

200

217b

216a
219

216
215 } 240
216a 215c 201
211c
211n 250

216b
219a
225
218
211b
215b
211d

214b
229
214a
215a
213
212b
212
212a
211a

211

211e

F I G. 2

F I G . 3

210

217a 217b

240 { 216
      215

216a
215c
211n 211c

250

219

201

218
211b
216b
215b
211d

219á
214b
229
214a

219a

215a

225

213
212b
212
212a

211a

211

211e

FIG. 4

F I G. 5

FIG. 6

Constants Material	E : Young's modules (N/m^2)	ρ :Density (kg/m^3)	σ : Poisson's ratio
Oscillation Plate (Nickel Steel)	2×10^{11}	7.8×10^3	0.28
Piezoelectric Element(PZT)	6.3×10^{10}	7.65×10^3	0.34

F I G. 7
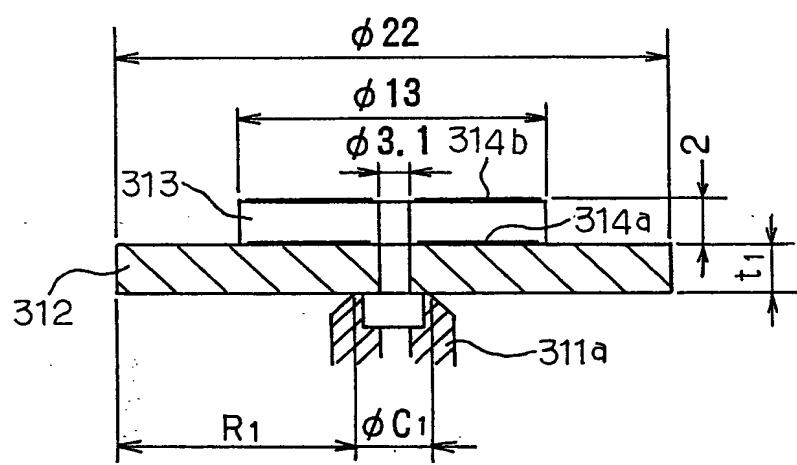
F I G. 8 A

Relationship between Thickness t_1 and
Sensitivity V_0 /Resonance Frequency f_0
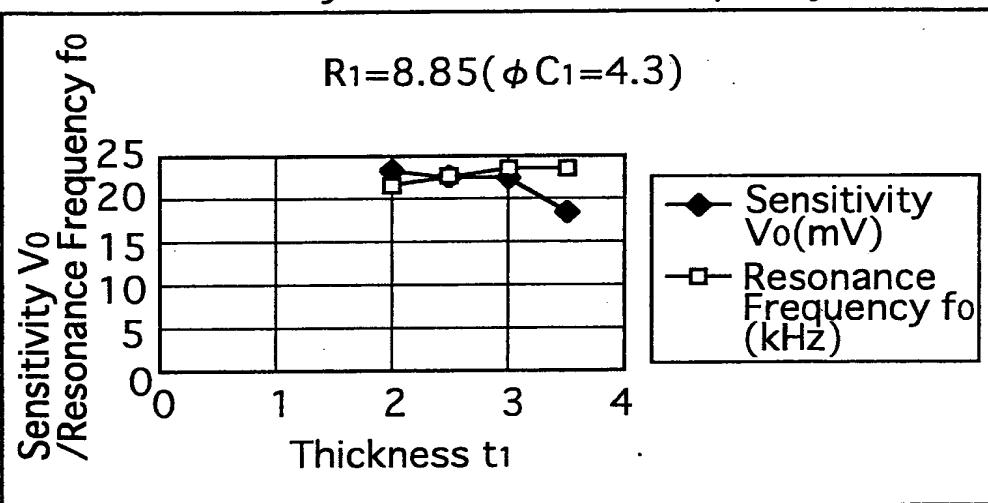
$R_1 = 8.85 (\phi C_1 = 4.3)$

Sensitivity V_0
/Resonance Frequency f_0

25
20
15
10
5
0

0   1   2   3   4
Thickness t_1

→◆— Sensitivity V_0(mV)

—□— Resonance Frequency f_0 (kHz)

F I G. 8 B

Relationship between Thickness t_1 and
Sensitivity V_0 /Resonance Frequency f_0

$R_1 = 8.15 (\phi C_1 = 5.7)$

Sensitivity V_0
/Resonance Frequency f_0

30
25
20
15
10
5
0

0   1   2   3   4
Thickness t_1

—◆— Sensitivity V_0(mV)

—□— Resonance Frequency f_0 (kHz)
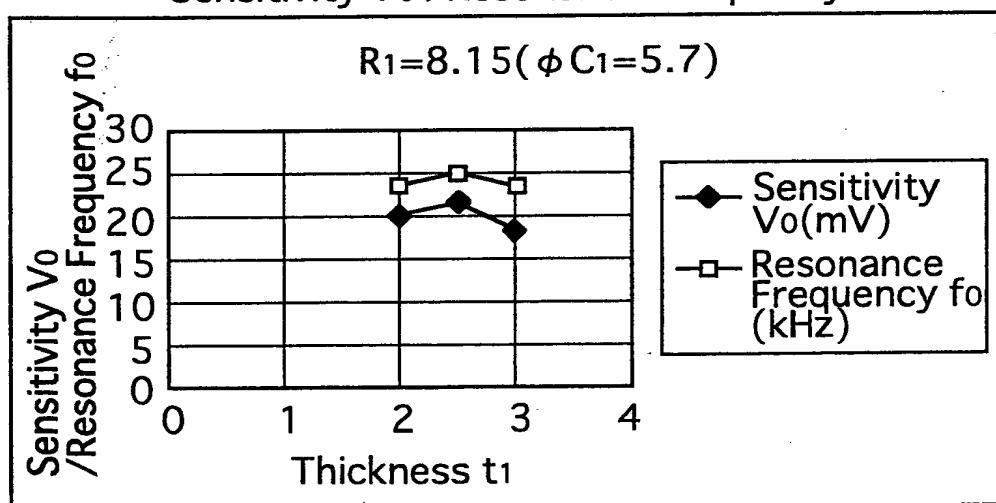
F I G. 9

F I G. 1 0 A

Relationship between Proportion of R_2/R_1
and Resonance Frequency f_0
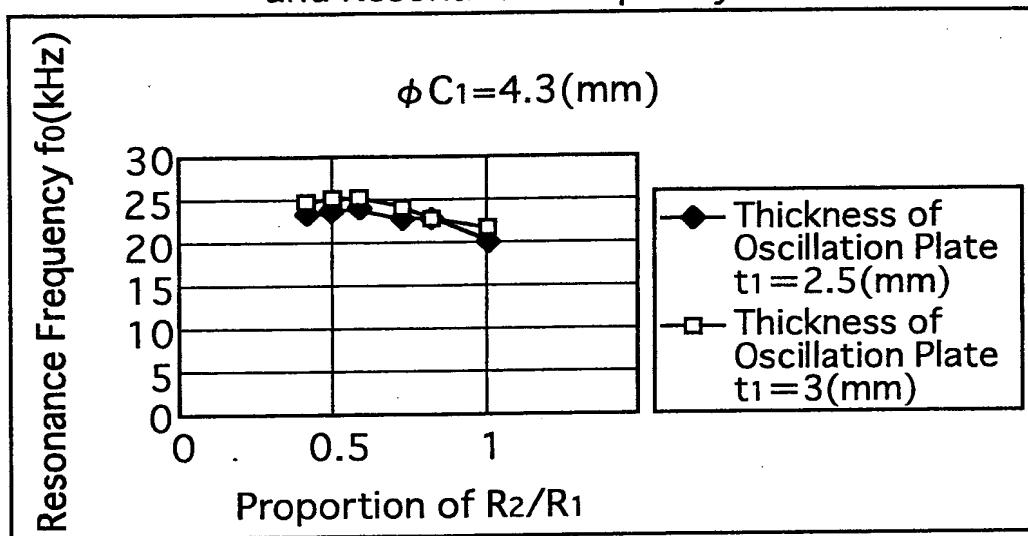
$\phi C_1 = 4.3 \text{(mm)}$

Legend:
- ◆ Thickness of Oscillation Plate $t_1 = 2.5 \text{(mm)}$
- □ Thickness of Oscillation Plate $t_1 = 3 \text{(mm)}$

Y-axis: Resonance Frequency f_0(kHz)
X-axis: Proportion of R_2/R_1

F I G. 1 0 B

Relationship between Proportion of R_2/R_1
and Resonance Frequency f_0

$\phi C_1 = 5.7 \text{(mm)}$

Legend:
- ◆ Thickness of Oscillation Plate $t_1 = 2.5 \text{(mm)}$
- □ Thickness of Oscillation Plate $t_1 = 3 \text{(mm)}$

Y-axis: Resonance Frequency f_0(kHz)
X-axis: Proportion of R_2/R_1
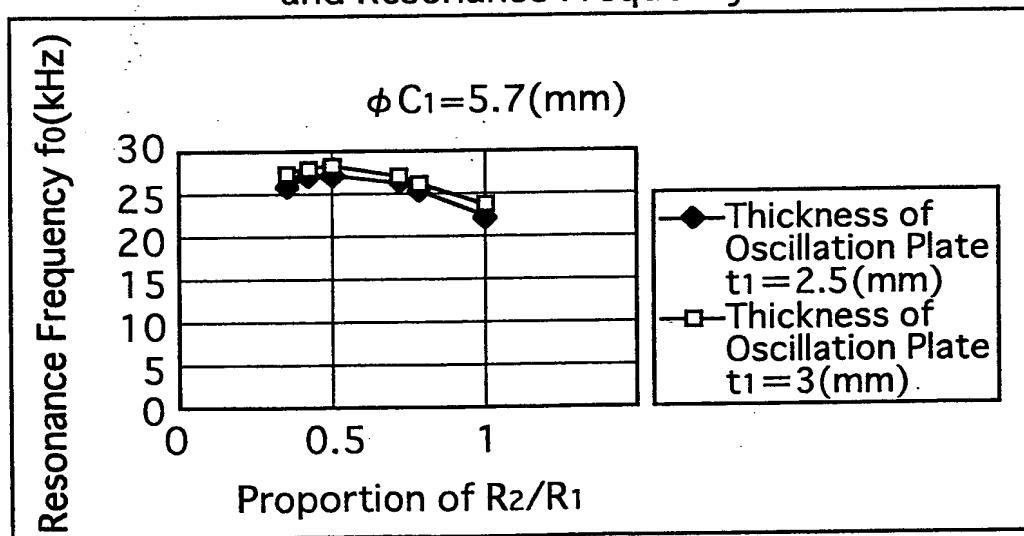
F I G. 1 1
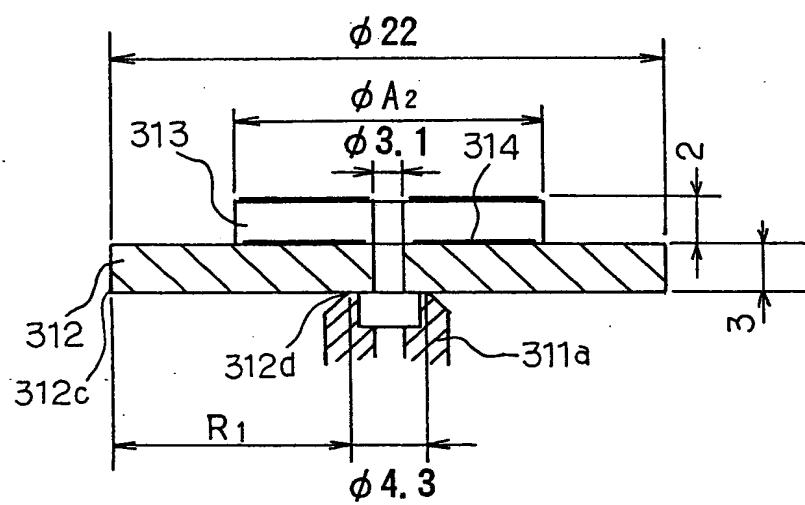
F I G. 1 2

Relationship between Proportion of R_2/R_1
and Sensitivity V_0(mV)/
Resonance Frequency f_0 (kHz)
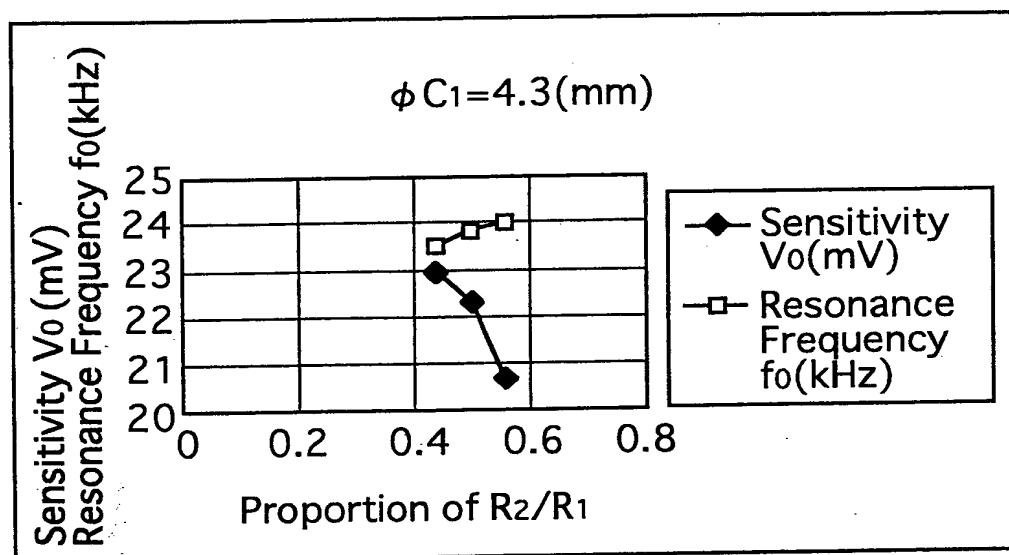
FIG. 13
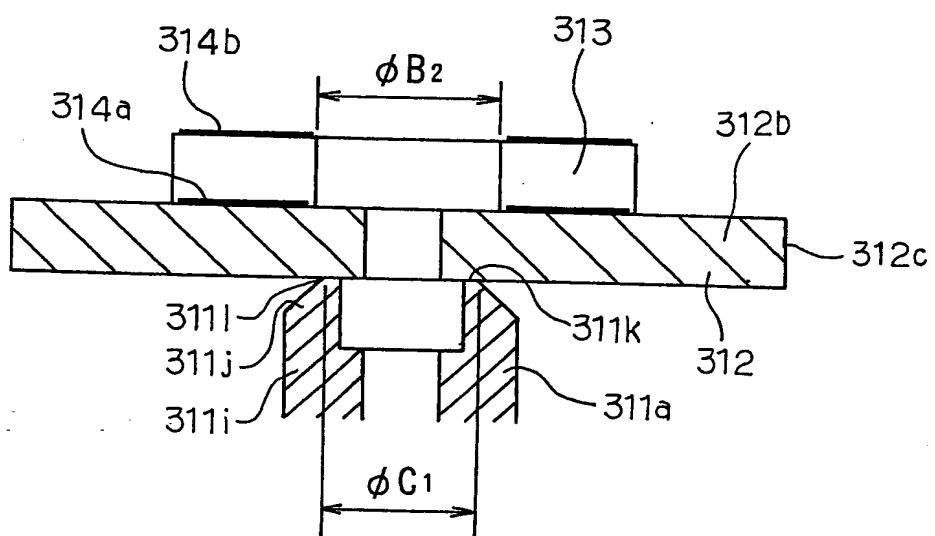
F I G. 1 4

Relationship between Sensitivity V_o /Resonance Frequency f_o,
Inner Diameter of Piezoelectric Element, i.e., B_2(mm)
with respect to Diameter of Supporting Portion, i.e., C_1(mm)

$\phi A_2/\phi B_2$ / ϕC_1		$\phi 13/\phi 4.9$ $t_2=2$		$\phi 13/\phi 3.1$ $t_2=2$	
		2	3	2	3
$\phi 4.3$	V_o	26.1	23.7	22.8	22.4
	f_o	21.0	23.5	21.5	23.8
$\phi 5.7$	V_o	22.1	18.0	19.9	18.2
	f_o	23.0	25.3	23.3	23.3

Outer Diameter of Oscillation Body $\phi A_1=22$(mm) V_o:(mV) f_o:(kHz)

F I G. 1 5

Relationship between Sensitivity Vo /Resonance Frequency fo,
and Proportion of Thickness of Oscillation Plate t_1
with respect to Thickness of Piezoelectric Element t_2

ϕC_1		t_1/t_2	0.67	1	1.25	1.5	2	3
$\phi 4.3$	$t_1=2$	Vo	20.7	22.8	22.5		22.7	
		fo	21.8	21.5	21.0		19.0	
	$t_1=3$	Vo		21.9		22.4		19.8
		fo		24.3		23.8		22.5

Outer Diameter of Piezoelectric Element $\phi A_2 = 13$ (mm)   Vo:(mV)   fo:(kHz)

F I G. 1 6

FIG. 17

Result of Experiments

φA1	φC1	φC1/R1 \ φA2	φ12	φ13	φ14	φ15	φ16
φ20	φ4.2	0.55	× 0.39				
φ20	φ5.7	0.80	× 0.47	× 0.46	× 0.37		
φ20	φ6.3	0.92	○ ≧0.57	○ ≧0.55	× 0.46		
φ20	φ7.3	1.15		○ ≧0.53	○ ≧0.53	○ ≧0.53	
φ20	φ7.3	0.99			× 0.51	× 0.49	
φ22	φ8.7	1.31			○ ≧0.53	○ ≧0.52	○ ≧0.52

- t1=t2=2(mm)
- ○(Pass): Spurious was not recognized
- ×(Fail): Spurious was recognized
- ○/×(Pass/fail) was judged at an upper limit frequency of the range of effective frequencies, i.e., 15(kHz).
- Values stated below ○ or × : f_{01}/f_0

F I G. 1 8

Result of Experiments

(dB)

Abnormal Noise(Spurious)
$f_0 1/f_0 = 0.39$

-20

-30

-40

-50

1   2   5   10   20 (kHz)
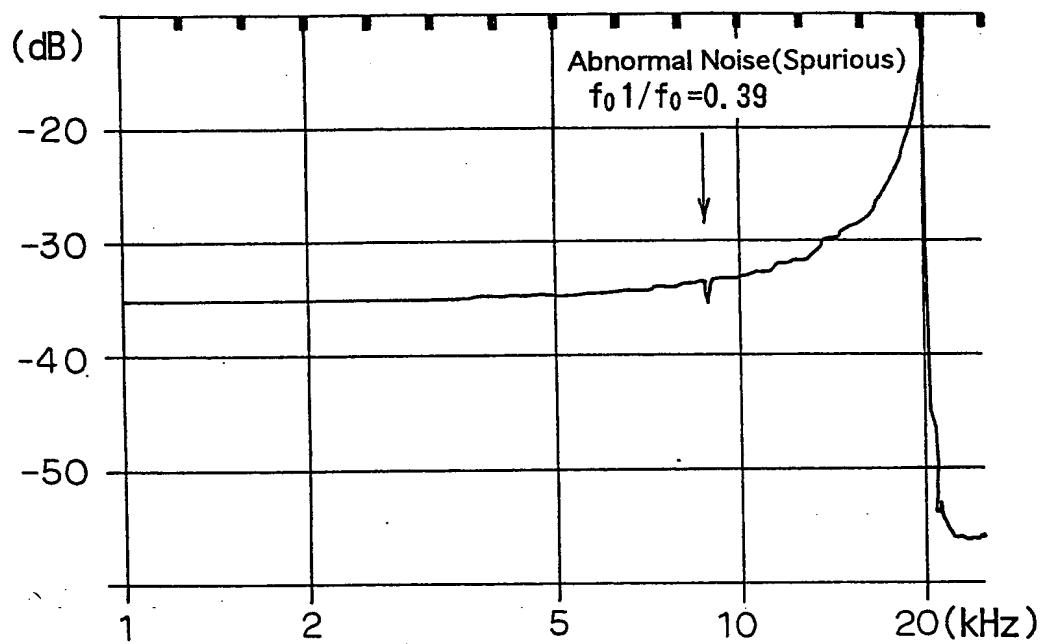
$\phi C_1 = 4.2$

$\phi C_1/R_1 = 0.55$

$f_0 = 23 (kHz)$

F I G. 1 9

Result of Experiments

(dB)

Abnormal Noise(Spurious)
$f_0 1/f_0=0.46$

-20

-30

-40

-50

1   2   5   10   20(kHz)
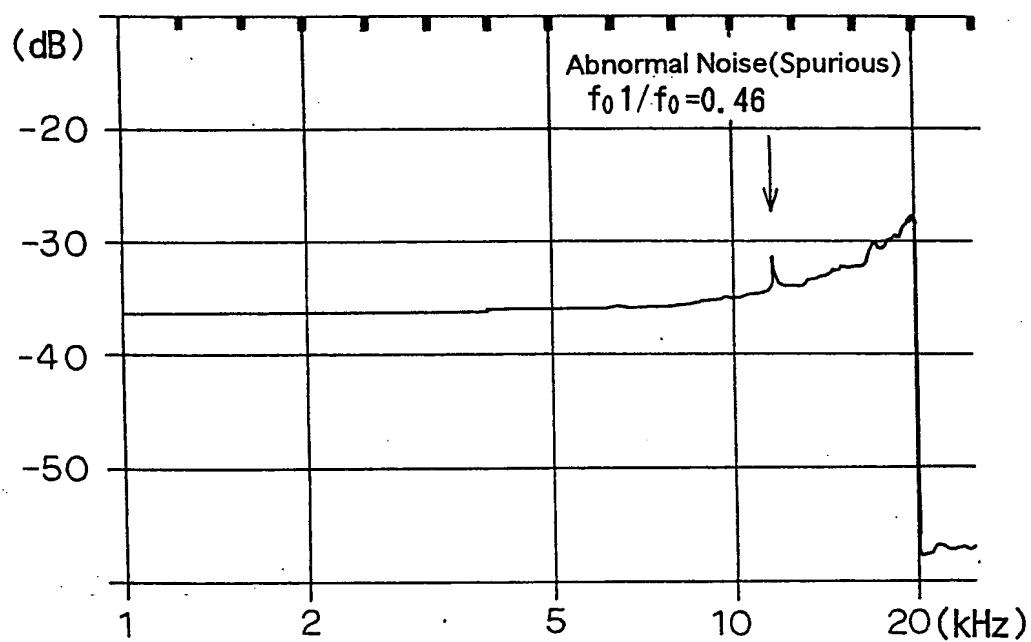
$\phi C_1=5.7$

$\phi C_1/R_1=0.80$

$f_0=26.3(kHz)$

F I G. 2 0

Result of Experiments
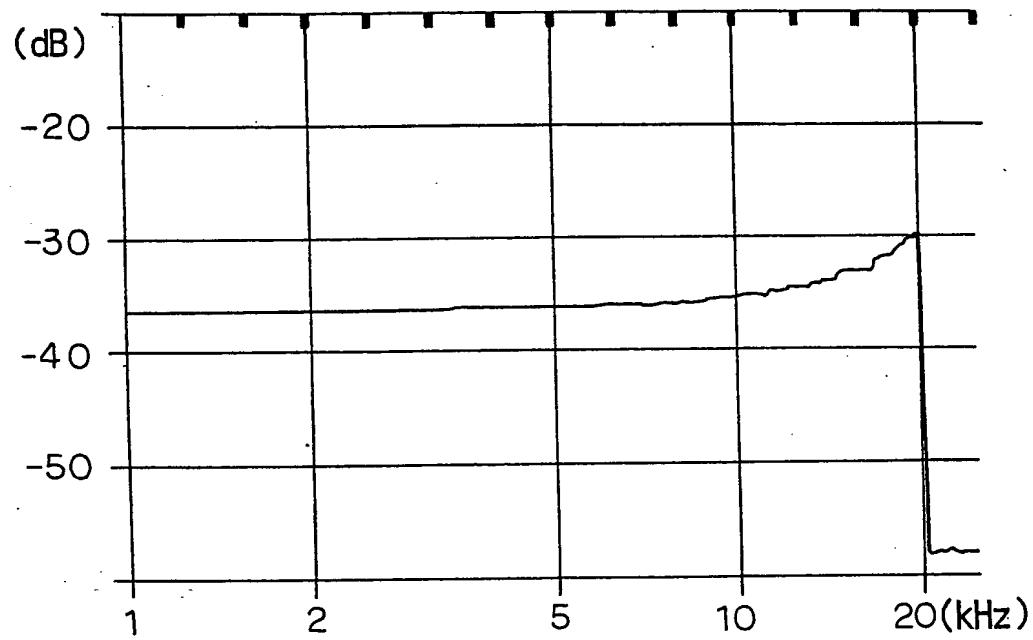
$\phi C_1 = 6.3$

$\phi C_1/R_1 = 0.92$

$f_0 = 27.3(kHz)$

F I G． 2 1

Result of Experiments
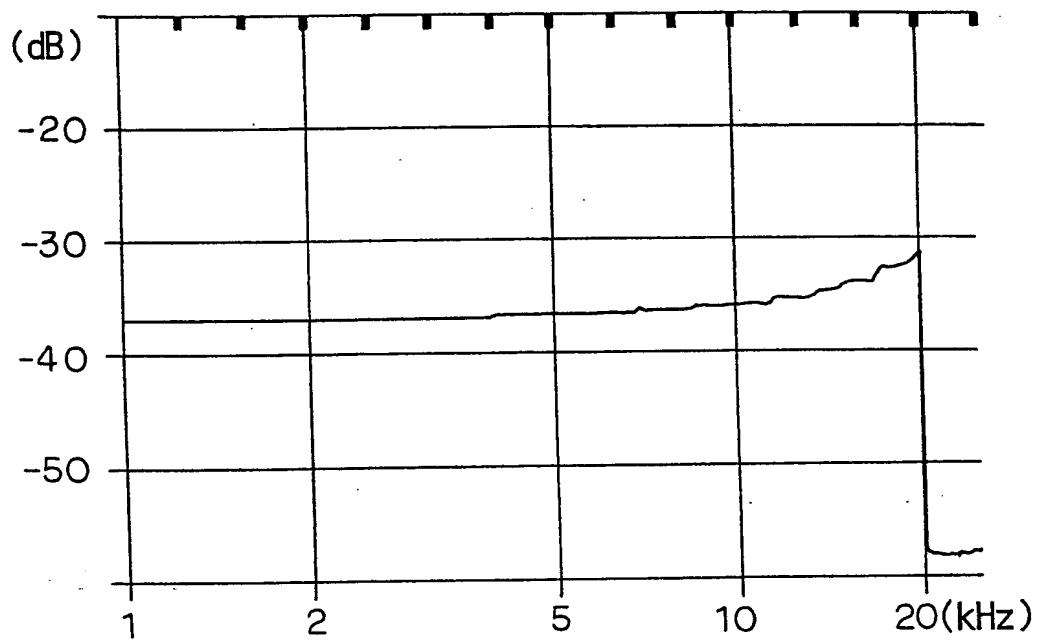
$\phi C_1 = 7.3$

$\phi C_1 / R_1 = 1.15$

$f_0 = 30.3 (kHz)$

FIG. 22

300

350

317b

316
365
319
340 { 316
      315

311n   311c
              301
                  318
                  311b
                  311h
                  315
                  315b
                  311d

314b
314a
360

325
313
312
312b
312a
311a

311g

311

311e

FIG. 23

310

317b

340

350

311c

318

311b

314a

311d

314c

313a

314d

312b

314b

312

312a

313b

360

311a

311

311e

311
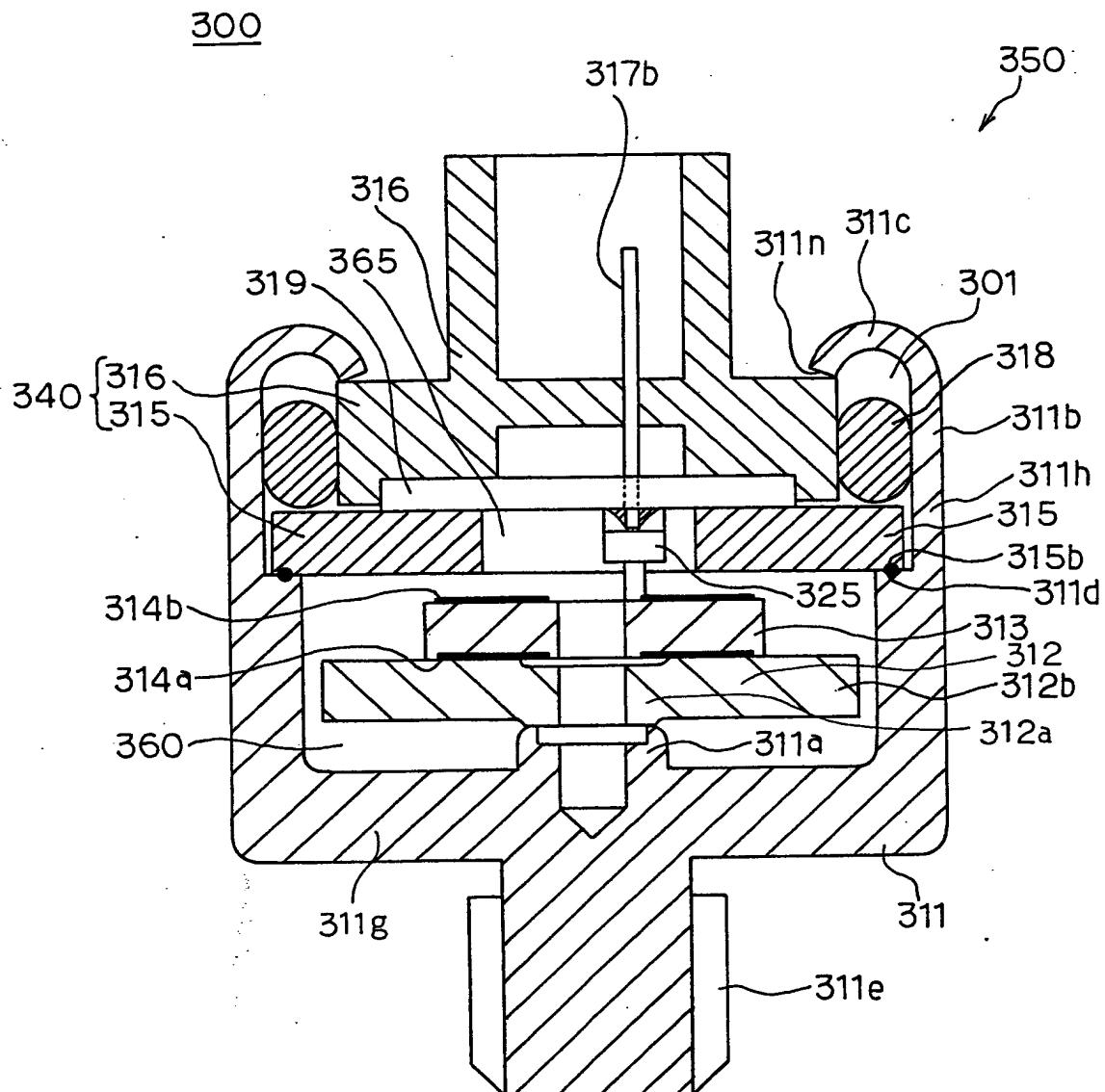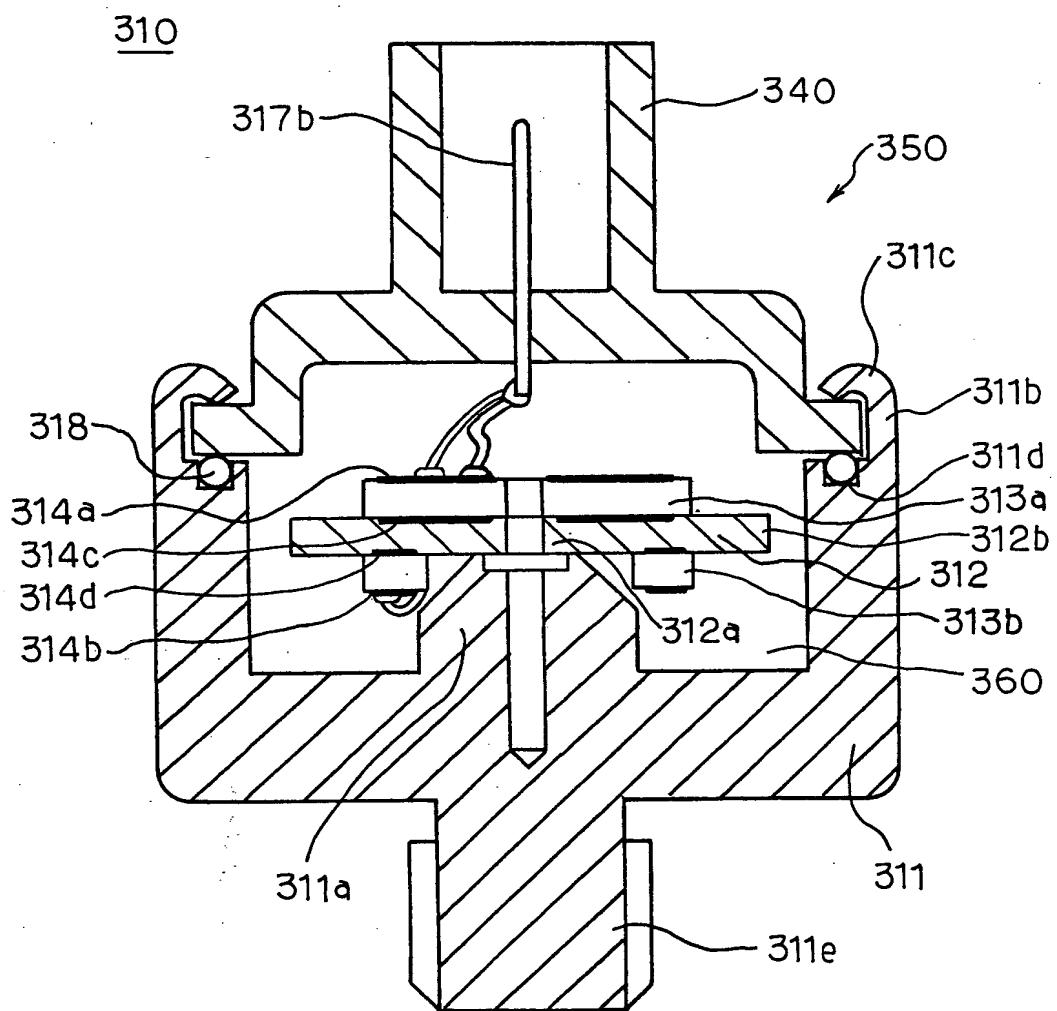
FIG. 24

FIG. 25

PRIOR ART

100
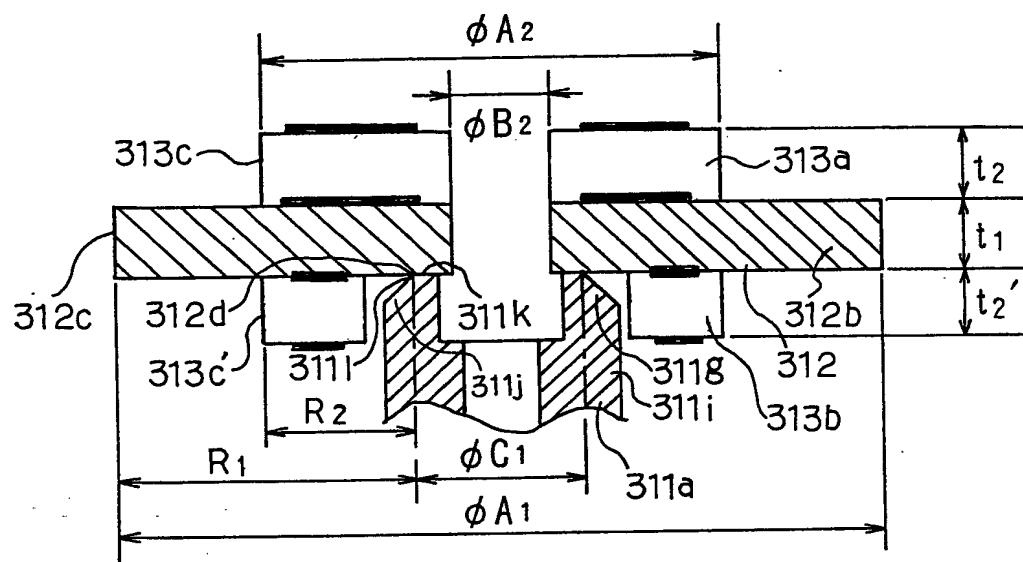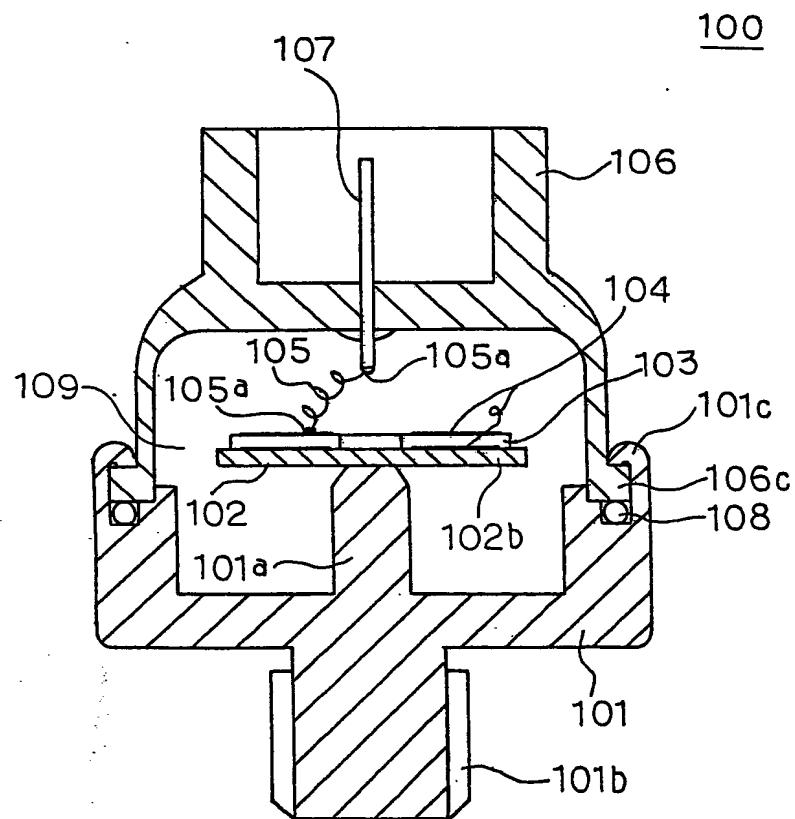
F I G. 2 6
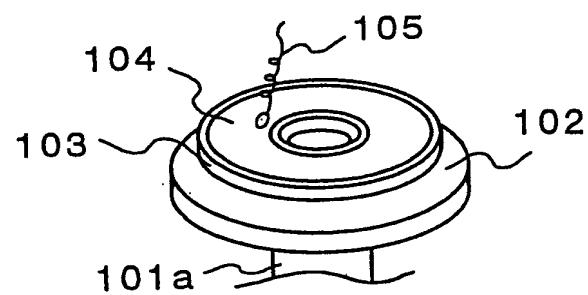
PRIOR ART

F I G. 2 7

PRIOR ART

<u>110</u>
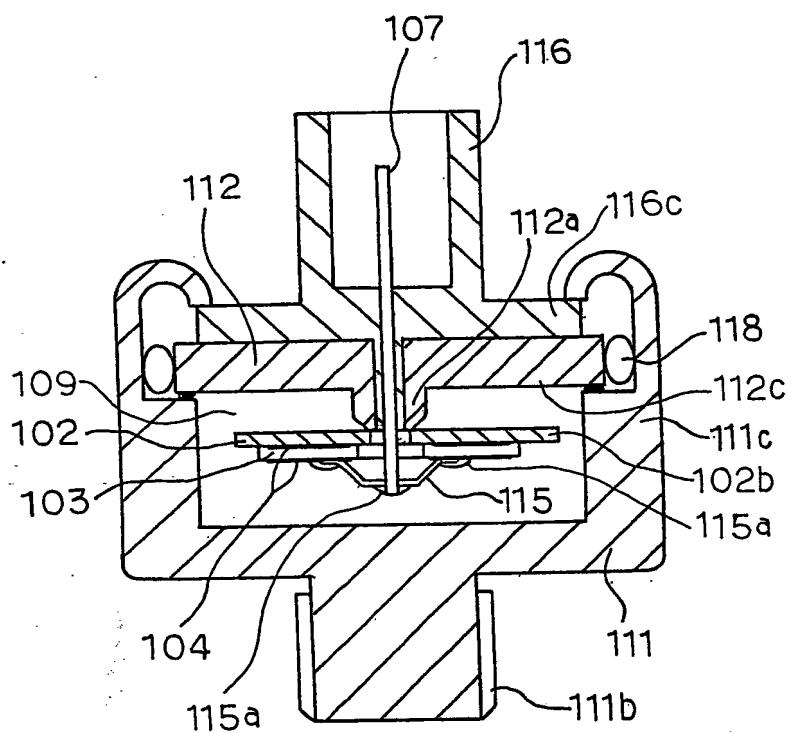
F I G. 2 8

Relationship between frequency f and output voltage V

F I G. 2 9

PRIOR ART

120

107   126
121c
129b   129
128
109   129a
127
125b
125a
122
125
124a   121
124b   123
121d   121b

FIG. 30

PRIOR ART

122

124

123
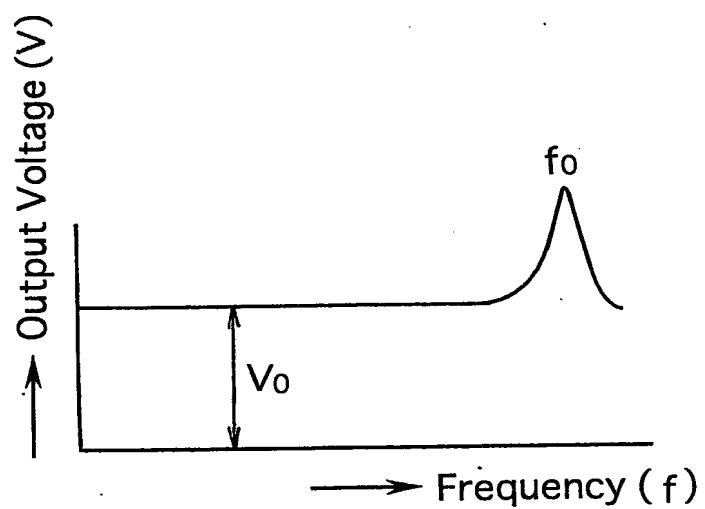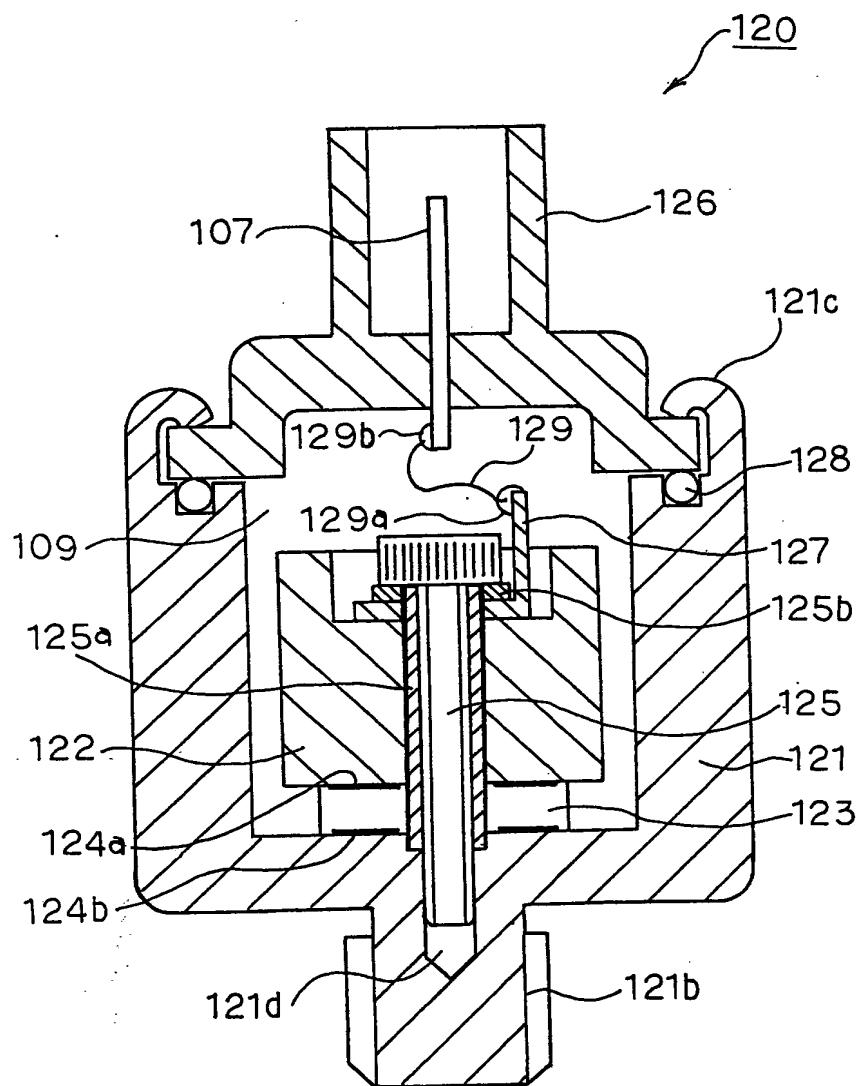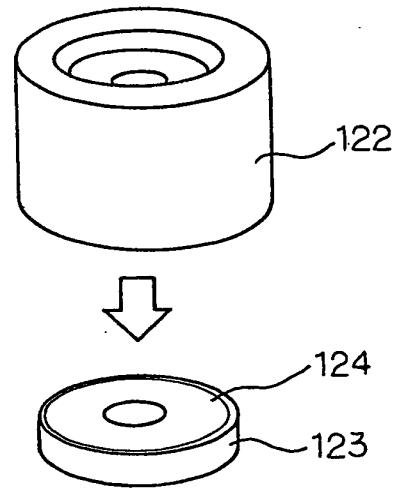
F I G. 31A

1/1 Oscillation Mode
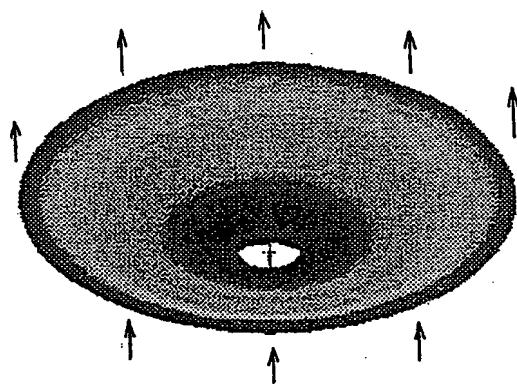
F I G. 31B

1/2 Oscillation Mode
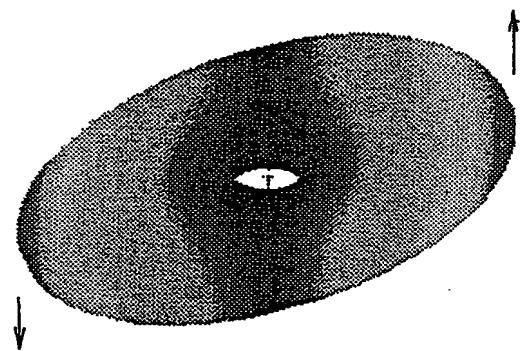
F I G. 31C

1/4 Oscillation Mode